Report of Proceedings

Eastern Experiment Station Collaborators' Conference on FLAVOR and TEXTURE of FOODS

October 30 & 31, 1962

EASTERN UTILIZATION RESEARCH & DEVELOPMENT DIVISION
AGRICULTURAL RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE
PHILADELPHIA 18, PENNSYLVANIA

Conference was held at the Eastern Utilization Research and Development Division with representatives from the State Agricultural Experiment Stations, universities, Quartermaster Food and Container Institute, Foreign Countries, and the U. S. Department of Agriculture participating.

This report summarizes the discussions of the various speakers during the conference. If further details on any particular subject are desired, they may be obtained by communicating directly with the person concerned (see appended list of names and addresses).

EASTERN EXPERIMENT STATION COLLABORATORS' CONFERENCE
ON FLAVOR AND TEXTURE OF FOODS
October 30 and 31, 1962

PROGRAM

Tuesday, October 30

8:30 a.m.	Registration	
9:30 a.m.	Introductory Remarks	P. A. Wells Eastern Utilization Research and Development Division
9:40 a.m.	Texture and its Measurement in Vegetable Products	A. Kramer University of Maryland College Park
10:40 a.m.	Objective Measurement of Texture in Food Products	Alina Szczesniak Research Center General Foods Corporation Tarrytown, New York
11:25 a.m.	Textural Characteristics of Dairy Products	W. F. Shipe, Jr. Cornell University Ithaca, New York
12:15 p.m.	Lunch	
2:00 p.m.	Factors Influencing Apple Texture	Robert C. Wiley University of Maryland College Park
3:00 p.m.	Determination of Meat Tenderness	Frances Carlin Iowa State University Ames
3:45 p.m.	Woodiness in Freeze-Dried Meat	R. A. Lawrie Low Temperature Research Station Cambridge, England
4:35 p.m.	Pectinase Inhibitor of Grape Leaves	W. L. Porter Eastern Utilization Research and Development Division

Wednesday, October 31

9:00 a.m.	Psychological Measurement of Food Properties	D. R. Peryam Quartermaster Food and Container Institute of the Armed Forces Chicago, Illinois
10:00 a.m.	Fruit Flavor Research	W. L. Stanley Western Utilization Research and Development Division Albany, California
11:00 a.m.	Chemical Changes Accompanying Flavor Deterioration of Vegetable Oils	C. D. Evans Northern Utilization Research and Development Division Peoria, Illinois
12:00 Noon	Lunch	
1:30 p.m.	Factors that Cause Chemical and Flavor Differences in Poultry	E. L. Pippen Western Utilization Research and Development Division Albany, California
2:30 p.m.	Chemistry of Dairy Flavors	E. A. Day Oregon State University Corvallis
3:30 p.m.	Chemical Factors in Meat Flavor	I. Hornstein Eastern Utilization Research and Development Division Beltsville, Maryland

INTRODUCTORY REMARKS

by
P. A. Wells, Director
Eastern Utilization Research and Development Division

It was pointed out that the present series of Collaborators' Conferences was initiated back in 1947, when Dr. E. C. Auchter was the Administrator of Agricultural Research in the Department and Dr. O. E. May was the Chief of the Bureau of Agricultural and Industrial Chemistry, under which utilization research was then conducted. They decided that collaborators should visit the Regional Research Laboratories once each year. At first these visits were made singly by collaborators at any time during the year, but later it was decided to hold 2-day conferences each year on different subjects, i.e., tobacco, potatoes, fruits, milk concentrates, methodology, etc., which the collaborators would attend. These conferences proved to be of great value in themselves, and have led to lasting benefits. Several of them have been continued on an annual basis by the respective industries. Regret was expressed that lack of room prevented industry representatives from attending the present conference.

Proceedings of the meeting will be prepared, consisting in general of 500-word summaries of the papers presented. A single copy of the proceedings will be mailed to each of those attending, and additional copies will be supplied on request.

TEXTURE AND ITS MEASUREMENT IN VEGETABLE PRODUCTS

by
Amihud Kramer
University of Maryland
College Park

Many difficulties, misunderstandings, and actual conflicts could be avoided, and real progress accelerated, if terms were clearly defined so that everyone employing the same term for a specific usage would be referring to the same thing. Webster's dictionary lists four definitions for the word Texture, all but one having little relation to our interest in the term as indicating a quality attribute of foods. Certainly the English language is flexible enough so that the same word or term may have more than one meaning, but for specific scientific usage, the term should be defined with mathematical precision. The one definition that has some application is: "the disposition or manner of union of the particles of a body or substance". If we ponder over this definition, would we not find that it applies equally well as a definition or perhaps more accurately, a description, of astronomy, or anatomy, or physics?

We must, therefore, create our own definition for this word Texture, if we wish to avoid confusion, and be sure that we are all talking about the same thing. The definition I am about to present is naturally the result of the work and experience gained by our group. Many of the concepts have been reported previously, but never perhaps as comprehensively or in a single presentation. This definition is suggested as a basis for discussion, with the hope that from this a generally agreed upon definition may be developed which will define the area occupied by texture as a quality attribute of foods, and differentiate it from other attributes of food quality.

I think we can all agree that when we speak of food quality, we refer to the esthetic satisfaction of the consumer, as sensed by the organs of sight, taste, smell, feel, and perhaps hearing, so that such attributes of quality must be sensory in nature, and their measurement would necessarily involve phychological tests. At the same time we are all keenly aware of the fact stated so clearly by Lord Kelvin almost a century ago:

> "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a very meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter be".

Thus if we are to include texture of foods in the category of scientific procedures, we should be able to explain it in numerical, or physical terms. We, therefore, arrive at our first broad delineation of texture, namely that it is psycho-physical, that is, sensory reactions measured in physical-numerical terms.

We now propose to confine texture further from the sensory standpoint, to the sense of feel only, and from the physical standpoint to the part of rheology which deals with the deformation or flow of matter, but only as a result of the application of forces greater than gravity.

Thus gel strength, for example, is a textural property, since force greater than gravity required to cause deformation and it is sensed primarily by mouth-feel, while consistency of a sauce is not a textural property, since its flow characteristics may be observed by the sense of sight, and flow occurs with the application of gravitational force alone. Similarly, and more obviously the tenderness of a beefsteak or a peach is textural, while the viscosity of an oil or syrup is not.

Having thus narrowed down textural measurements as those in which forces other than gravity are employed, let us consider how these forces may be applied. We find four possible methods:

1. Compression, in which the force applied may reduce the volume of the object, or change its shape without dividing it. Examples of its common usage are feeling a breakfast roll for freshness, or peach for "yielding quality". A proper application of this principle was made by Hartman and Isenberg in their study of onion storage when they compressed onions between two plates and determined the force the onions would withstand before the onset of historesis, that is, before they failed to return to their original shape upon removal of the pressure. The use of the pressure tester on fresh peaches for this purpose is not correct, since the pressure tester is forced into the peach flesh, so that the test is not one of compression, or yielding quality, alone, but of shear as well. The new adaptation of the pressure tester where the reading is obtained after the plunger has passed a certain distance into the side of the peach, but before shearing is encountered, is a more correct application of the compression principle. The firmometer, developed by Kattan, is also a more proper method for measuring this yielding quality, and has been used on tomatoes, sweet potatoes as well as peaches.

2. Tensile strength may be considered the reverse of compression, where the object is torn, or pulled apart by the exertion of forces applied away from the center of the object. An example of its common usage would be the act of tearing a slice of bread in half, or pulling apart a piece of candy. The application of force in this manner to the evaluation of food quality is rather rare. It is, however, found as part of the Standard of Quality promulgated by the Food and Drug Administration for canned green and wax beans, where the toughness of the strings is measured by clamping a given weight to the bottom of the string. If the string tears, the string is not tough.

3. Cutting force may be defined as achieving the separation of an object into two or more parts, without changing their shape. It is obvious that if a cutting operation were performed perfectly with no compression or other forms of force involved, the cutting edge would have no width, and the force required would be infinitesimal. Thus a certain degree of compression, shearing, and perhaps even tensile forces are involved with these so-called cutting operations, where the sharpness, or thickness and bevel of the cutting edge is involved and should be specified. Examples of the common usage of such applications of force abound, since most civilized consumers cut food with the use of knives, forks, or spoons rather than use tensile forces in which they would tear the food apart with the hands. A good example of the application of this principle in a food testing devise is the Wilder Fiberometer used to determine the fibrousness, or "fork cutting quality" of asparagus.

4. Shearing force is defined as that force which causes two contiguous parts of an object to slide relatively to each other in a direction parallel to their plane of contact, so that here we obtain both a separation in the object, as we have when cutting force is applied, but also a change in position. Here again it is practically impossible to obtain shearing without some degree of compression or extension preceding the shear action. Thus with some preceding compression, shearing action is perhaps the most common of the ordinary expression of texture in foods, essentially resembling the chewing action of the teeth. In fact, an instrument was designed by Proctor and his associates at the Massachusetts Institute of Technology which was named the denture meter, and which consisted of a set of dentures. The forces required for chewing the sample with these teeth, were measured by the use of a strain gage dynamometer.

Actually such measurements of shear-compression have been made by the use of many instruments for many years. Perhaps the first of these to gain wide acceptance and general use, was the fruit pressure tester first proposed by Morris in 1917, and some of the many forms of penetrometers used by different individuals for measuring gel strength. More recently, the texturemeter, the tenderometer, and the shear-press were successively more elaborate, more precise, more accurate, or more calibratable instruments, capable of measuring this same quality attribute. Thus from the manner in which force is applied, any one of the above instruments, including the fruit pressure tester, may be appropriate for measuring the chewiness of an apple, peach, or tomato. However, to obtain a measure of "yielding quality", the above instruments are not applicable, but the Kattan firmometer, or the pressure tester adapted with a sleeve and light, may be, since they simulate the action of the palm of the hand, and the ball of the thumb, respectively.

Measuring the force

Since we are dealing with the application of force in one form or another, our measurement must be in terms of pounds of force utilized at a specified moment in time, this being usually at the point of the maximum use of force; or it could be in terms of work accomplished, which would be the force employed during the entire period of time in which the sample was tested. Most of the earlier and simpler instruments employed the compression of a spring, calibrated in terms of lbs. (e.g. pressure tester), or grams (e.g. Chatillon puncture tester), and force was applied by hand. Here the problem of precision is immediately apparent, since a more rapid application of force will result in a higher reading of force at an instant in time. Also a less uniform application of force tends to result in a higher peak value. The use of a hydraulic gage and gears such as used in the texturemeter is of some help in this case, but creates other problems such as presence of air in the hydraulic system, and friction errors. A completely automatic, motorized system which provides the opportunity

of selecting a particular speed of stroke, and maintaining the same speed uniformly, as is available in the tenderometer and the shear-press is the solution. In the process of providing a uniform application of force, the tenderometer, however, lost its calibratability so that it is not possible to test a tenderometer, and determine whether the lbs. per square inch are true or in error to some degree.

In practical use, a value indicating the maximum point of force application at a moment in time is frequently sufficient to indicate some textural property of a substance, particularly when the test is in the nature of a failure test, and peak force is applied at the moment of failure. A more nearly complete description of textural properties, however, can be obtained with a determination of total work done, such as is obtainable when force in lbs. is recorded continuously with time for the entire period during which force is exerted on the substance. This can be accomplished with a shear-press equipped with a recording attachment. Thus, for example, if a jelly sample is inserted in the shear-cell of the shear-press, the resultant time-force curve will show an initial rise, the slope of which will indicate the compressibility of the gel. The peak will indicate the force required to break the gel, and the down-slope will indicate the shearing properties of the gel. The integrated value for the area under the curve will indicate the amount of work expended, in terms of pound-inches. Thus if the sample is rubbery, the initial slope of the rising curve will be low, since the product will yield considerably before breaking, but the peak may be high, and the down-curve steep. On the other hand, if the sample is brittle, the ascending slope would be steep, the peak probably not as high, and the descending slope less steep.

Sampling

Sampling is an integral part of any testing procedure. Generally, the larger the sample, the better the precision and the accuracy of the test. It is for this reason that a penetrometer type test is not desirable, since the precision of the test depends upon the infinitesimally small sample which is being penetrated. A rod like plunger such as is used with the pressure tester is a little better, and multirod, or bar probes such as are used in texturemeters, tenderometers or the shear-press are substantially better. However, except when applied to single units which in themselves are sufficiently large to be tested by such multiple probes, such a test provides sum, or average, measurement of the bulk sample, but would provide no information on the distribution of textural quality among individual units within the sample. For example, a penetrometer test of a kernel of corn provides information on the toughness of that kernel, and perhaps one hundred such determinations would indicate the distribution of kernel toughness or the percentage of tough kernels in the lot. If on the other hand, a sample consisting of several hundred kernels were placed in the shear-press, the single value obtained

may be equivalent to the average of the hundred or more individual determinations obtained with the penetrometer, but there would be no means of knowing the percentage of tough objectionable kernels present. Thus if the presence of objectionable or defective units is the main purpose of the test, then the advantages of the bulk sample must be sacrificed to obtain such information, and the more tedious, time consuming procedure utilizing single probes must be used. The time and tedium required in this type of test may be obviated by the use of equipment which would orient, count, present the units to the probe, sort, and tally them automatically. Such equipment is currently in the process of construction.

In many instances determinations on single units are unnecessary because they are highly correlated with determinations on bulk samples. When the product unit is small, as a pea, or a rice kernel, its chewiness is not determined on an individual grain basis since a spoonful is chewed simultaneously, so that the average of that spoonful is sensed, rather than the presence of a single kernel. Our studies with asparagus indicated a close correlation between shear-press values on bulk samples, and percentage of stalks or pieces of stalks containing excessive amounts of fiber. This was found to be true for unsorted lots of material arriving from the field, and was explained on the basis of increasing variability in fibrousness with increasing average fibrousness. Thus asparagus lots which were on the average very tender, apparently came from fields where only stalks which were sufficiently developed were harvested. Lots which were on the average more fibrous, apparently originated from fields where stalks which were insufficiently developed were also harvested; however, the stalks which developed sufficiently so as not to be fibrous were also present, thus causing at the same time a higher average fibrousness, and also a higher percentage of fibrous stalks. This increase in variability coincident with increase in average fibrousness persisted until about 50% of the stalks were fibrous. Beyond that point average fibrousness continued to increase as did the percent of fibrous stalks, but variability in fibrousness among the stalks began to decrease again.

Accuracy of the test

Accuracy of a measurement is the degree to which it measures that which it purports to measure. Thus in setting about to find a method for measuring a sensory quality, we should strive to simulate as closely as possible the actual sensory stimulus which we wish to measure. If we wish to measure the sensations obtained in chewing, we could do no better than to construct a synthetic mouth complete with teeth, tongue, etc. We are, however, immediately confronted with the fact that we could not do this completely, at least not at any reasonable price, and secondly, we would encounter very serious problems of standardization and calibration. In other words, our difficulties would multiply when we would build a second synthetic mouth which is to be identical with the first or what is more to the point would provide us with identical results on duplicate samples.

We must, therefore, resort to simpler geometric models to use as simulators of hand or mouth parts. These can be manufactured with sufficiently close tolerances, so they can be interchangeable, and calibratable. An understanding of the forces involved in textural measurements and methods of application can help us in selecting a design that may eventually prove to be a satisfactory method of measuring that textural attribute which we wish to measure. The final proof, however, that our method is accurate, is obtainable only by reference to the human sensor, who is the only authority for ascertaining not only whether a particular test is or is not satisfactory, but also, which of a number of possible tests, is the most accurate.

Here we are confronted with some long enduring, ingrained concepts, which were and still are extremely useful in the quality evaluation of vegetables, but at this time are also responsible for much of the confusion existing in the evaluation of texture. I refer to the terms of maturity and ripeness. These words in turn require definition, and although I do not know whether our definitions will be generally acceptable, we found them to be useful, for our purposes. We think of maturity and ripeness as referring to the age, that is the stage of development of the plant organ. Maturity applies specifically to vegetables, and generally implies that the immature, or less mature vegetable is the more desirable. Thus, for example, small peas that have not as yet grown to their full seed size are preferable to the fully grown peas. Small bean pods where the seeds have just begun to develop are preferable to large pods with well developed seeds, etc. Ripeness applies more specifically to fruits, and generally implies a preference to the riper, or more developed product. Thus a fully ripe, soft peach is preferable to an unripe, green peach. Obviously the preference for immature vegetables or ripe fruits must be within limits. For example, a good method for measuring maturity-tenderness of sweet corn was about to be rejected during standards hearings because of what appeared to be a poor correlation between the test results and panel results for tenderness maturity. A closer scrutiny of the data, however, revealed that some extremely immature, by the objective method, were scored down by the panel as being undesirable. Similarly, a fruit that is ripe to the point that it is mushy, discolored, and rotten, is too ripe to be considered top quality.

In attempting to evaluate food quality objectively, these concepts of maturity or ripeness may lead to confusion, because they are concepts rather than distinct parameters, and usually include more than one attribute of quality. Thus when the maturity, or tenderness, or character of a vegetable is to be evaluated (all these terms appear in the standards for grades of the Agricultural Marketing Service) texture is involved, but its measurement is confounded by the involvement of other attributes of quality such as flavor, size, or structure, and perhaps even color as is the case with lima beans and asparagus.

Thus, although, from a theoretical standpoint we would like to see grades and standards of quality based on distinct parameters each of which would be measured objectively, and we would certainly recommend this as a long term objective, we must at the same time recognize that less clearly defined attributes such as tenderness-maturity, or character, do exist and our efforts at developing test methods must be directed towards their solution as well. In doing this we frequently find that a single objective procedure is rarely the complete answer. We do have an example of such a rare situation with raw peas for processing, where a compression-shear test by the use of the tenderometer or shear-press appears to provide a complete answer to the measurement of the tenderness-maturity factor of quality. With sweet corn, on the other hand, we found that a complete determination of maturity could be obtained only with three tests. These consisted of a test of moisture or density; a test for pericarp, or skin toughness; and a test for kernel size. Although the relation of the first two tests to textural values as sensed by mouth feel, particularly chewing, could be readily understood, certainly a test for kernel size would have little to do with texture, or the sense of feel, but rather with the sense of sight. Nevertheless it was demonstrated at a high level of statistical significance that kernel size was a significant factor in the human evaluation of maturity of sweet corn kernels.

When the recording attachment to the shear-press became available, an attempt was made to find a completely instrumental method to replace this tri-metric test. A time-force curve of shear looked promising, since the curve developed two characteristic peaks, the first and lower peak was thought to indicate compressibility and to be associated with the starchiness of the corn, or its density, while the second higher and sharper peak would be an indication of the force required to shear the pericarp, and would, therefore, be associated with toughness of the skins. Although these relationships were statistically significant, they were not sufficiently accurate for prediction purposes, and the only useful value on this curve was the second peak which was closely correlated with skin toughness. Density of the kernels was measured adequately by the use of an adaptation of the compression principle, in which the quantity of juice extracted during compression was measured. These two determinations with two cells of the shear-press were found to give an adequate indication of maturity. Apparently the influence of kernel size was obtained incidentally when the shear test was performed, since the smaller kernels were pushed out through the slits of the shear-cell, and did not require shearing.

In all the work which we have done thus far on practically all of the major vegetables, we have found only one practical application of the time-force curve. This was the determination of wholeness and drained weight of canned tomatoes. In this procedure, total contents of a can of given size are transferred to the shear-cell.

Since the liquid, and small pieces of tomatoes pass through the slits in the bottom of the shear-cell, the higher the drained weight, the greater the area under the time-force curve. At the same time, the firmer the tomatoes, the more likely they are to maintain their wholeness, and consequently raise the peak value of maximum force.

For other products, namely sweet corn, peas, green beans, lima beans, asparagus, broccoli, satisfactory evaluations of textural properties were obtained using the appropriate shear, compression, or cutting cell, and noting only the peak value at which maximum force was applied.

OBJECTIVE MEASUREMENT OF TEXTURE IN FOOD PRODUCTS

by
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General Foods Corporation
Tarrytown, New York

Texture is the least well described of the many organoleptic food attributes of concern to a food scientist. Of the several reasons which caused this situation one should mention the lack of an adequate bridge between theoretical rheology and practical application, and the fact that most of the work in the field of food texture reported to-date had a definite end result in view and dealt with a well defined food product. Only in the last few years have some attempts been made to define texture, and these are not devoid of the influence of the prevailing trend to identify texture with just a few characteristics most common to a particular food in question.

Definitions of texture published by various workers point out two important elements of texture: the physical structure of the material,--or its geometry, and the way the material handles and feels in the mouth,--or its mechanical and surface properties. In our work at General Foods, we consider texture as the composite of the structural elements of food, and the manner in which it registers with physiological senses. Thus, this definition includes the concepts of "texture" and "consistency" (or "body") as defined by other workers.

The food scientist wants to describe texture in terms of numbers in order to affect better quality control and assess new processes and new products, and in order to develop theoretical generalizations and hypotheses.

Objective measurements of texture may be divided into three categories.

(1) Fundamental tests which measure fundamental rheological properties and which are concerned with forces, deformation, and time (e.g. vector tests)

(2) Empirical tests which measure parameters indicated by experience to be related to textural quality (e.g. penetrometers, compressors, consistometers, shear measures, etc.).

(3) Imitative tests which imitate conditions to which the material is subjected in practice (e.g. butter spreaders, farinograph, amylograph, Volodkevich bite tenderometer, etc.).

The Volodkevich bite tenderometer attempted to imitate the action of teeth on the food. Probably the best adaptation of this apparatus is the MIT denture tenderometer, designed to simulate the denture surfaces and motions of mastication in the mouth. This instrument was selected for our research work at General Foods because of its potential applicability to measuring a spectrum of textural characteristics rather than a selected few. It underwent considerable modification to make it more reproducible and easier to operate.

The General Foods Texturometer consists of an articulator moved at a predetermined constant rate by a variable pulley drive motor and equipped with a plunger. The test sample is placed on a plate under the plunger and its resistance to the "chewing" force is detected by a pair of strain gages mounted under the plate. The strain gages are part of a Wheatstone bridge. Impulses from the strain gages, caused by the unbalance of the bridge, are passed through an amplifier and recorded on a fast speed Leeds and Northrup strip-chart recorder. Any desired number of consecutive chews may be recorded and the time-force curves obtained are interpreted in terms of an organized texture nomenclature.

This organized texture nomenclature was developed based on a compilation of terms used in popular texture terminology, an analysis of their meaning, and definitions of rheological concepts involved. In studying the meaning of terms popularly used in description of texture, one finds that while some refer to what might be called "primary" characteristics, many refer to "secondary" characteristics, i.e. those which could be adequately described by two or more of the primary terms. In addition, one finds that many popular terms actually denote degrees of the same characteristic and could be considered points on a scale--e.g. soft, firm, hard.

We group the textural characteristics into three main classes:

(1) mechanical

(2) geometrical

(3) others, referring mainly to moisture and fat content of the food.

The mechanical characteristics are manifested by the reaction of the food to stress, while the geometrical characteristics are reflected mainly in the appearance of the product.

The Texturometer measures the type and intensity of the mechanical characteristics of texture. These are divided into:

(a) primary characteristics--hardness, cohesiveness, viscosity, elasticity, and adhesiveness

(b) secondary characteristics--brittleness, chewiness, gumminess

It can also be adapted to measuring the amount of fat and moisture released on chewing.

For measuring viscosity, the Texturometer is fitted with a modified cup containing strain gages mounted on a fixed baffle arm, and a Lucite paddle is substituted for the conventional plunger.

The recorded Texturometer curves represent a texture "profile" from which the primary textural parameters can be read off. The secondary parameters are derived mathematically from the obtained numbers.

At the present stage of development, the Texturometer simulates the mechanical chewing motion, but does not have as yet provisions for temperature control and moisture injection. Foods that change in texture depending on moisture content are evaluated after equilibration to reach the required moisture values. Those that change in texture depending on the temperature are evaluated after equilibration in a constant temperature oven.

Reproducibility of Texturometer readings is very good. Coefficients of variation vary with the parameter and the type of food--the latter factor being a reflection of the heterogeneity of the tested product. Correlation with sensory evaluation also depends on these factors. Excellent correlation was obtained on foods selected as standards for scales set-up for the various parameters, and good agreement was obtained on a number of other products, both commercial and experimental.

TEXTURAL CHARACTERISTICS OF DAIRY PRODUCTS

by
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According to my classification scheme, texture includes many characteristics. For the purpose of this discussion, texture is used to refer to all characteristics of dairy products which produce a tactual response. Some of my dairy colleagues would not agree with such a general definition. They would exclude

characteristics that have been classified under such categories as body, consistency and apparent viscosity. They would argue that texture refers to structural characteristics. I would agree but ask them if they were referring to visible structure or molecular structure. Certainly non-Newtonian viscosity differences can be attributed to structural differences at the molecular or intermolecular levels. We need to consider structural differences at all levels.

The dairy industry has not been as concerned about textual characteristics as some other segments of the food industry. This lack of interest has been due in part to an unawareness of the importance of texture and in part to the lack of tools for objective measurements of texture. Most of the work on texture has been focused on butter and cheeses in other countries whereas our primary interest has been with ice cream. The physical characteristics of fluid dairy products has received more attention in this country than elsewhere.

Many questions remain because of our lack of knowledge. I will start with one of these questions: "How important is the texture of milk?" Some may reply that milk does not have textural qualities. If it does not, then what do people mean when they say that skim milk is thin or watery as compared to whole milk? Certainly at least some of the differences between skim and whole milk are sensed by the feeling in the mouth. The role of apparent viscosity and oiliness in producing these differences has not been established clearly. Skim milk can be modified to make it more like whole milk by adding either solids-not-fat or fat. If solids-not-fat are used it is necessary to add levels that significantly alter the viscosity, whereas fat has an effect at levels below that necessary to significantly alter the viscosity.

Until recently the dairy industry had not paid much attention to skim milk. In view of some current food fads, interest in skim milk is now more than merely academic. The tactual qualities of skim milk should be considered in our efforts to increase consumer acceptability of skim milk.

There are those who claim that they can differentiate between tactual qualities of homogenized and nonhomogenized milk. Certainly homogenization has a pronounced effect on the whipping and churning qualities of cream. This effect is associated with changes in the fat globule membrane, which one could classify as a structural change. Another type of structural change is also produced by homogenization, namely the destabilization of protein. This effect manifests itself when homogenized cream is added to coffee--the cream tends to feather (i.e. the proteins coagulate). Coagulation of protein in evaporated milk is also enhanced by homogenization.

The temperature treatment of cream has very marked effects on the viscosity. The changes in viscosity are related to the crystalline state of the fat and the nature of the fat globule membrane. The

temperature of separation of milk has an effect on the distribution of the euglobulin, agglutinin, between the cream and skim phase. This in turn affects the viscosity of the cream.

A tremendous amount of work has been done on determining the factors affecting the texture of butter. I do not have time to review the literature on this subject. I can summarize by quoting from McDowall of New Zealand, "The physical properties of butter largely depend on (a) the size and nature of the butterfat crystals; (b) the extent of crystallization; (c) the amount of liquid butterfat expressed from the globules to serve as a continuous phase, either lubricating the passage of solid particles over one another, and so giving spreadability, or, if too much is present, showing up as 'greasiness' with rise in temperature; (d) the extent of destruction of the fat globules ....so affecting the amount of solid fat in the liquid phase."

Control of the texture of cheese still presents some real problems. A variety of devices have been developed to measure the consistency of cheese both in the manufacturing and ripening stages. Most of these devices are useful aids to texture control if they are used. Too often the industry has been reluctant to use these devices. For example, some are still relying on such "tests" as the sensation produced when a cheesemaker squeezes a handful of green curd. I suppose this sort of test works if you have trained hands, but if not, your consumers turn to your competitor's product.

The texture of cheese is primarily dependent on the composition of the cheese, especially the relative amounts of protein, fat and water and the extent and nature of the protein alteration. There is a very close relationship between the texture and flavor of cheese, particularly in the hard cheeses. An experienced judge can often predict the flavor on the basis of the texture. A pasty cheese is likely to have a bitter and fermented flavor whereas a mealy cheese usually has an acid flavor.

The uniformity of the texture of process cheeses is probably one of the major reasons for its popularity.

Of the dairy products ice cream presents some of the most interesting problems. For example, one needs to control ice crystal growth, and to stabilize the air that is whipped into the product. The most common control measure is to use stabilizers such as gelatin, gums or alginates. However, the use of stabilizers may affect the apparent flavor by affecting flavor release. One of the major ice cream manufacturers in the East does not use stabilizer because he feels that the full flavor is not released from a stabilized ice cream. If too much stabilizer is used the ice cream will be soggy or gummy. Incidentally, to my knowledge no one has ever determined how smooth an ice cream the consumer wants. You often hear people say they would like

some old-fashioned home made ice cream. One of the characteristics of home made ice is the coarseness and relative rapid melt-down. Stabilizers tend to eliminate coarseness and fast melt-down, but is this what the consumer wants? We need more consumer preference studies regarding texture.

If an ice cream manufacturer uses stabilizers, he is faced with a choice of a variety of commercial products. How can he objectively evaluate these products? This raises the key question--How do stabilizers function? How do they prevent or retard the formation of large ice crystals? There are those who believe that the stabilizer absorbs on the face of ice crystals and prevents further growth of the crystals. Others attribute the action of the stabilizers to their water binding capacity. However, neither of these theories has been proven. In an effort to get a better understanding of the effect of stabilizers on ice crystal formation we undertook some studies on their water binding capacity using the freezing point method suggested by Gortner in 1922.

At the outset of this study we noted a contrast between the freezing behavior of true solutions and colloidal suspensions. Our experiments indicated that changes in freezing behavior are correlated with changes in viscosity. However, it is postulated that the differences in freezing behavior are due to reduction in convection and migration of solute rather than to viscosity changes per se. These experiments will be described in a forthcoming publication.

In conclusion, I would like to emphasize the need for more basic information on the factors affecting texture and on consumer preferences in regard to texture.

FACTORS INFLUENCING APPLE TEXTURE

by
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Texture and particularly firmness of processed apple slices is influenced by the variety, maturity, and storage history of the raw apple as well as in-plant processing techniques and handling. Earlier work has shown that textural aspects of processed apple slices accounted for about half of the quality grade.

In exhaustive studies on apples conducted at Maryland it was found that the pectic substance did not account to a very large extent for variations in firmness. Kertesz has reported that little indication could be found that the initial firmness in apples (at harvest) is directly related to total pectin content or to the proportions of the

various fractions. He does indicate, however, that changes in firmness which occur after harvest and during storage are probably related to pectic substances.

Evidence is accumulating then, that polysaccharides other than pectic substances may play an important role in the initial firmness of an apple variety at harvest, in changes that take place during ripening in storage and in those changes that occur during thermal processing.

In this study the alcohol-insoluble solids (AIS), the structural materials have been fractionated into starches, pectinic acids, hemicelluloses and celluloses. They have been related to the firmness of the raw fruit and canned fruit on both a fresh-weight and an AIS proportionality basis to determine the importance of each component singly and in conjunction with the others.

Methods: Samples have been processed according to the regular commercial procedure. The raw slices were submitted to 4 minutes of vacuum at 29 inches, and then this vacuum was broken with steam up to a pressure of 7 lbs. for 20 seconds. The slices were taken from the vacuum-pressure retort, placed in tin cans, and processed for 8 minutes at 212°F.

Starches have been extracted with perchloric acid and measured colorimetrically at 620 mu. Pectic substances from separate aliquots of AIS have been extracted with 0.25% ammonium oxalate and 0.25% oxalic acid and measured in sulfuric acid in the ultra violet range (296 mu). Celluloses were obtained by treating AIS residues with 0.25% ammonium oxalate and 0.25% oxalic acid to remove pectic substances, 33% chloral hydrate (2, 2, 2-trichloro-1, 1-ethanediol) to remove remaining starches and soluble hemicelluloses, and 10% KOH to remove the more insoluble hemicelluloses. These extractions were carried out at 75°C, and filtered with nylon cloth. The "cellulose residue" remaining contained only the very insoluble cell wall material.

Shear-press determinations reported in lbs.-force have been made on both raw and processed slices. Canned slice firmness, wholeness and sloughing have been evaluated by 15 experts representing the apple processors in Maryland, Virginia, Pennsylvania, and West Virginia.

Summary of Results

(1) Changes in raw apple tissue during final phases of maturation on the tree and ripening in early cold storage appears to hold the key to economically important texture changes in processed apple slices.

(2) Because there is a poor relationship between raw slice firmness and thermal processed slice firmness while raw apples

contain starchy substances, problems involved in both texture changes and their interrelationships must be carefully studied. Results indicate that processed slices of a less firm raw apple may actually give a firmer thermal processed slice than those from a firmer raw apple slice. This should be carefully qualified by stating that this is true during early harvest times or in high starch apples. This does not hold true, for example, in a late harvest Golden Delicious which has dissapated most starches prior to harvest.

(3) Raw slice and processed slice firmness become parallel at the time that starch and the pentosan-hexosan polyuronide complex (P-H-P Complex) are no longer evident in the tissues of the raw apple.

(4) Organoleptic ratings for texture indicate that optimum texture in slices occurs at the time these starchy components are dissipated from the tissues. This also coincides rather well with optimum color and flavor quality.

(5) Data indicates that in thermal processed slices the cellulose content (the highly insoluble cell wall material) is primarily responsible for firmness. Firmness in processed slices appear to rise and fall in direct proportion to the amount of this highly insoluble cell wall material.

(6) Because of the high inverse relationship between starchy components and cellulose, it should be possible to use the starch test as an indicator or analytical tool to predict the firmness of processed slices during the starchy cycle, the best processing time and temperature for uniform firmness, and the cellulose content which is very difficult to measure quickly. Firmness predictions of low or non-starchy processed apple slices may be made directly from physical firmness measurements of the raw product.

(7) In raw apples, basic firmness changes, particularly in early harvest apples, is due to an intricate set of circumstances. The P-H-P complex, a hemicellulose, appears to be the key substance in the normal maturation and ripening cycle. Experiments have shown this substance to be heat labile and released from the pectin-cellulose complex by heat treatment. Indications are that this is a precursor to cellulose and evidently the cellulose is not fully developed in the immature apple.

(8) The utilization of highly insoluble wall thickings (cellulose) as the principle ergastic substance in the metabolism of the raw apple after the decline of the starchy components seems possible. After starch loss in the raw apple, cellulose declines on a fresh weight basis. This loss does not seem to compensate fully for the softening that takes place in both raw and processed apples. Cell slipage and related softening during this part of the life cycle of the raw apple involve the hemicelluloses and most likely the pectic substances. This softening after about 2 - 3 months in cold storage does not seem to be as economically important to processors as those changes which take place earlier in the season.

Taken in part from:

Factors Influencing Apple Texture. Robert C. Wiley and G. E. Stembridge. Proc. Amer. Soc. Hort. Sci. 77: 60-72 (1961). The work described was done under a research contract with the Eastern Utilization Research and Development Division.

MEASUREMENT OF TENDERNESS IN MEAT

by
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Introduction

One could speculate and argue at length as to the importance of tenderness in the consumer's decision to buy or reject a piece of meat. It is a matter of record, however, that research on tenderness of meat has captured the interest and attention of scientists for at least 65 years. Each succeeding year seems to point up the complexity of the problem rather than produce any answers or solutions. As early as 1897, Lehman and co-workers studied the causes for the toughness of meat and determined tenderness of meat mechanically. Their results were published in 1907. I shall mention the factors that are related to tenderness and then discuss objective and subjective methods used to determine tenderness.

What factors affect the tenderness of meat? No attempt will be made to evaluate these factors and not all of them have been shown to bear a direct or indirect relationship to tenderness. However, a consideration of the possible factors may give us some clues as the methods to use in measurement of tenderness. Also the long list points up the complexity of the problem and makes one wonder why we try to get a machine that only measures one characteristic and pretend that it will be an adequate measurement of tenderness. The following are some of the factors related to tenderness of meat: The extrinsic factors include: Heredity and Environment; Breed; Sex (castrated--hormonized); Maturity or age; Feed management and type of feed (including additives, range and feed lot); Body type and confirmation; Amount of exercise; Condition at time of slaughter; Amount of struggle during slaughter; Finish--external fat on carcass; Aging or ripening of carcass (time and temperature). The Intrinsic factors include: Physical characteristics; Marbling; Color (lean, fat), etc.; Firmness of flesh; Type of cut and muscle; Area within the muscle; Diameter, length, elasticity, cohesiveness, density or compactness of muscle fibers; Size of muscle or bundles of fibers; Chemical composition (protein fat collagen, hydroxyproline, elastin, mucoprotein or mineral content); Distribution

of fat, connective tissue; pH of muscle; Mechanical treatment (pounding, cutting, grinding); Additives (acid, salts (PO_4), enzymes); Xray treatment (tender-ray, freezing, drying); Method of cooking (Moist or dry, in foil or bag, Time and temperature -- electronic or Conventional).

The Methods of Measuring Tenderness may be divided into chemical, physico-chemical, physical, and organoleptic.

The chemical methods include Proximate composition (Nitrogen, Fat, Mineral, Amino Acids); Connective tissue - amount and character (Collagen, Elastin, Hydroxyproline, Mucoprotein); The physico-chemical methods include pH, conductivity measurements, Histological (specific components, condition of fibers, distribution); The Physical methods include Elasticity of fibers; Size - diameter/length of fibers; Compactness - resistance to penetration; Water-holding capacity; Density - resistance to pressure; resistance to Shearing; resistance to grinding (crush & shear). The Organoleptic or Sensory methods include paired eating tests, ranking tests, and scoring tests (quantitative and qualitative).

The interdependence of flavor, tenderness, and juiciness may be measured. The number of chews required may be used as a measure of tenderness.

The objective measurement of tenderness is complex because it must reflect the action of the teeth in cutting, shearing, tearing, grinding, and squeezing, and because the exact meaning of the word tenderness varies with the food, i.e. meat, pie crust, and peas. Hence, it is not surprising that there are many ways to measure tenderness.

Instruments for measuring the kinesthetic characteristics of meat include penetrometers, food grinders and shear-press devices which try to simulate the action of the teeth in compressing and then shearing the food. In 1957, Schultz presented an excellent review on mechanical methods of measuring tenderness. Only a few of the methods used will be discussed and some developments since 1957 will be mentioned.

The shear method most commonly used was devised by Warner and Bratzler between 1928 and 1933. This instrument has a steel plate 1/32" thick with a triangular hole in it. The samples of meat, an inch or one-half inch cores, are placed in the opening and the force required to pull the dull blade through the meat is recorded on a spring-type, self-recording dynamometer. In numerous studies in which the Warner-Bratzler-Shear devices was used, shear values obtained on meat samples correlated to the extent of approximately 0.70 with panel scores for tenderness. The most recent modification of Warner-Bratzler machine (Spencer and Jacobson, 1962, at Washington University) to increase the sensitivity and reliability of the apparatus and also to produce a load-time history has replaced the

spring measuring device with an electrical force transducer and recording system. It has a cantilever beam with strain gages on both sides. Further research is being done to determine correlations between taste panel scores and total work using the newly modified Warner-Bratzler apparatus.

The Kramer shear press used primarily for measuring tenderness in vegetables is now used in some laboratories for meat.

The basic unit consists of a hydraulic drive system for moving of a piston at any predetermined rate of travel, adjustable from 15 to 100 seconds for full stroke. Automatic limiting pressure and fast return of drive piston are provided.

Measurement of force is provided by the compression of a proving ring dynamometer, similar to ones used by National Bureau of Standards for calibration of testing machinery. Different rings are available capable of providing ranges from 100 pounds for relatively soft materials, to 6000 pounds for hard products. Readings may be obtained from gauges fitted into the proving ring, or electrically by the use of transducers. Where an electrical measuring devise is used, a recorder may be attached to obtain a time-force curve for the entire stroke, instead of a mere maximum force reading.

The test cell is attached directly to the proving ring, thus eliminating any possible frictional error, since the force developed by the resistance of the food material to shearing or compression is transferred directly to the measuring system. The standard test cell consists of parallel stainless steel blades which precisely mesh with the sample box.

A recently developed instrument for evaluating fish also has been used on weiners. The test cell is rather like the one in the Lee Kramer press except it is hinged at the back, like jaws.

In 1955, Miyada and Tappel described a modification of a Christel Texturemeter by attachment of an electric motor and reduction gears. Also, a food grinder was used to measure tenderness. An A.C. ammeter in series with the motor of the grinder was used to obtain readings at 5-second intervals. The total energy expended in grinding the sample was obtained from a plot of power consumption in watts as a function of time.

Later in 1960, Schoman, Bell and Ball reported on variations and their causes in the electric meat grinder method of measuring beef tenderness. Emerson and Palmer in 1960 compared a food grinder - recording ammeter apparatus and the Warner-Bratzler shear apparatus to a taste panel of 4 judges as methods of evaluating tenderness in beef. They concluded that the Warner-Bratzler shear apparatus appears to be more precise than the food grinder since higher correlations between taste panel and

Warner-Bratzler shear (-.79 to -.53 for different trials) than between taste panel and food grinder (-.48 to -.24 for cooked and raw meat). They stated that taste panel was found to be the most repeatable method, closely followed by the Warner-Bratzler shear and the food grinder method. Of course, the choice of a device for measuring tenderness of meat will depend to some extent on the purpose of the investigation. For example:

Hiner and coworkers at the U.S.D.A. in Beltsville have been concerned about a device that would measure tenderness of a small sample of raw or cooked meat, give results quickly and be easy to operate and give accurate results on a sample small enough for a biopsy.

In 1959, Sperring, Platt and Hiner reported that results obtained with the tenderness press, a modification of the Carver juice press, showed good correlation with organoleptic scores and with the Warner-Bratzler shear press.

There are a few general statements that can be made concerning the above methods. Samples to be tested and compared must be of uniform size (with the same orientation of muscle fibers in some cases); testing must be done at a single temperature, preferably in the range of 0°C to 7°C; several replicate tests must be run on each sample, and the sample variability established before any valid evaluation of results can be made. Results obtained on raw meat (beef) are of little value as an indication of tenderness of cooked meat. If the precautions listed above are observed, shear or other objective "tenderness" measurements on cooked beef may correlate quite well with taste panel test evaluation of tenderness.

"WOODINESS" IN FREEZE-DRIED MEAT

by
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Irrespective of the improvements over earlier meat dehydration procedures achieved by the Accelerated Freeze-Drying process (AFD), one major defect remained; "woodiness" of texture or "toughness" in the rehydrated, cooked meat. Obviously the muscle proteins are deleteriously altered during the freezing or drying phases of the AFD process. In attempting to elucidate these changes, much initial effort was devoted to studying the microscopic appearance of myofibrils, the extractability of muscle at various ionic strengths, the degree of myofibrillar swelling and the water-holding capacity of AFD treated muscle. It was hoped that the state of the muscle proteins, as thereby revealed, would reflect the organoleptic impressions; but it became evident that the muscle proteins were also subject to influences independent of the AFD process. Thus, it was noted that

with the approach of the summer months, rehydration of myofibrils took place with increasing difficulty, despite the fact they were derived from meat dried at a plate temperature of only 30°C. The state of muscle proteins, including their water-holding capacity, is much influenced by pH and, for two reasons, it was suggested that the ultimate pH of the pig psoas muscles employed as raw material might be an important source of variability. Firstly, the ultimate pH of the psoas muscle of normal pigs is one of the most variable encountered in meat animals. Secondly, the source of the pig psoas muscle used in the study was a group of Landrace animals in which the incidence of "white muscle disease" was fairly high. In the latter condition, the water holding capacity of muscle proteins is lowered by a very high rate of pH fall during post mortem glycolysis and/or by the attainment of an abnormally low pH. Furthermore, the condition appears more frequently in the summer. A relationship between "woodiness" of texture (after rehydration and cooking) in meat which had been subjected to the AFD process and its ultimate pH was thus implicated. A high ultimate pH seemed desirable, which was induced by pre-slaughter subcutaneous injection of adrenaline (700 µgm per kilo). Rabbits were used in the preliminary experiments. L,dorsi muscles from injected and control animals were subsequently freeze-dried, rehydrated, cooked and tasted. The procedure was effective based on histological, biochemical, and organoleptic evaluation.

As was evident from histological sections and determinations of water-binding capacity, the degree of rehydration of freeze-dried muscle of high ultimate pH was superior to that of the control muscle. Moreover, as determined by taste panel, the rehydrated samples of high ultimate pH were regarded as tender. Their texture had the resilence of non-dehydrated meat and "woodiness" was absent-- although it was noted in all rehydrated samples from freeze-dried meat of normal (low) ultimate pH. These results justified extension of the experiments to beef animals.

Identical twin steers of Aberdeen Angus--Jersey breed were employed in the hope of lessening differences due to inter-animal variation. One of these was injected subcutaneously with adrenaline (100 µg/Kg) at 24 hr and again at 4 hr preslaughter. The other twin, which was not injected, served as a control. The left side of each carcass was dissected into its constituent anatomical muscles. Semimembranosus, biceps femoris, psoas major, l,dorsi (lumbar), l,dorsi (thoracic), and deep pectoral muscles were frozen at -20°C. The values for the ultimate pH of the fresh muscles were compared, from which the effect of adrenaline in depleting the glycogen reserves, and thereby in raising the ultimate pH, was apparent.

To prepare the meat for dehydration, slices 12 mm thick were cut from the whole frozen muscle. Each set of 6 slices taken

consecutively along the muscle comprised one unit. From each unit two slices wrapped in polythene pouches were held frozen at -20°C and the remainder were freeze-dried by the AFD process. After drying each unit was separately sealed in a can and gas packed under nitrogen.

Dehydrated whole steaks were reconstituted by immersion in water for 20 min. During this time corresponding frozen steaks were thawed out in water. The samples were then casseroled (in the immersion water) in an oven at 185° for 1-1/2 hr. To assess texture a taste panel (8 members) was asked to place the samples in order of increasing toughness and dryness, and also to indicate "woodiness" when it was detected. From the results obtained, the effectiveness of a high ultimate pH in improving the texture of beef was clearly demonstrated. The treated (frozen) sample was placed first ($p = 0.05$) in tenderness & juiciness. This improvement was maintained after drying; the treated dehydrated sample being placed second ($p = 0.05$). The control (frozen) sample, which was third, was only slightly different from the control dehydrated meat, except in the incidence of "woodiness", which was greatest in the latter.

Objective measurement of toughness by tenderometer confirmed the findings of the taste panel. The frozen meat of high ultimate pH was the most tender. The dehydrated muscles of high ultimate pH were in most cases more tender than the corresponding control (frozen) muscles; and in all cases, more tender than corresponding control dehydrated muscles.

Samples stored at -20°C and +37°C were examined after 4 months. Organoleptic assessment indicated that tenderness, juiciness and flavor of the meat with a high ultimate pH were much the same whether storage was at -20°C or 37°C. On the other hand control samples of low ultimate pH were considerably tougher and drier when stored at 37°C than when stored at -20°C although no off flavors were reported. At both temperatures of storage, the superiority of texture of the meat of high ultimate pH, over that of low ultimate pH, was maintained. Measurement by tenderometer confirmed these findings on toughness.

Although the glucose content of the meat of high ultimate pH was low compared with that of the control meat, both browned on storage. Nevertheless, the degree of browning was greater in the latter.

Naturally attempts have been made to explain these organoleptic results biochemically and histologically. As in the rabbit, it was found that there was an increase in the amount of water absorbed during reconstitution in all rehydrated muscles of high ultimate pH in comparison with corresponding muscles of low ultimate pH.

Determination of the amount of water absorbed by myofibrils at different pH values also proved a useful means of studying the alterations brought about in the muscle proteins by differences in ultimate pH. The results demonstrate that different muscles responded in varying degrees to a high ultimate pH. The pH/swelling curve for the 1,dorsi (lumbar) was practically the same for treated (frozen), treated (dehydrated) and control (frozen). However, all the other muscles from the treated meat absorbed more water than corresponding controls, the greatest increase being found with psoas and the biceps femoris. With the exception of 1,dorsi (lumbar) all the treated muscles had a lower water holding capacity after dehydration, the drop being approximately the same for each muscle. It might seem that the beneficial increments in water holding capacity and in tenderness of freeze-dried meat having a high ultimate pH ought to be simply obtained by rehydrating meat of normal (low) ultimate pH, with a buffer of high ultimate pH. The relationship between swelling of the myofibrillar protein fraction of biceps femoris and the pH of the medium was determined for (a) muscle of ultimate pH 6.7 (treated) at its own pH, (b) muscle of ultimate pH 6.7 after homogenates had been adjusted to pH 5.6, (c) muscle of ultimate pH 5.6 (control) at its own pH and (d) muscle of ultimate pH 5.6 after homogenates had been adjusted to pH 6.7. It was found that the water-holding capacity of myofibrillar protein of high ultimate pH was reduced considerably by lowering the pH of the homogenate, whereas that of myofibrillar protein of low ultimate pH was only slightly raised by increasing the pH of the homogenate. It seemed possible that the lowered water-holding capacity of the myofibrils derived from meat of low ultimate pH could be due to loss of water-binding contribution from the sarcoplasmic protein fraction and/or diminution of myofibrillar water-binding capacity, possibly by precipitation of the sarcoplasmic protein onto the myofibrillar surface, as in pork muscle, when the rate of the post mortem glycolysis is very high.

In further attempts to establish the biochemical basis for the "woodiness" or toughness of AFD meat attention has been directed to the sarcoplasmic proteins. It has been shown that both the rate of pH fall during post-mortem glycolysis and the ultimate pH affect the quantity of the sarcoplasmic proteins which remain in solution.

From the quantities of protein precipitated by lowering the pH of whole sarcomplasmic protein extracts of 1,dorsi from 7.2 to 5.8 and 5.0, it was clear that there is more precipitable sarcoplasmic protein in solution at an environmental pH of 5.8 than at pH 5.0, that more is in solution where the rate of post mortem glycolysis has been relatively slow, and that extracts from muscles of high ultimate pH have a greater quantity of precipitable sarcoplasmic protein than those prepared from corresponding muscles of low ultimate pH. Indeed this is so at all environmental pH values from 4.5 to 7.0. Attempts have been

made, by using starch gel electrophoresis to identify the sarcoplasmic protein constituents involved.

The principal fraction investigated so far is that part of the sarcoplasmic proteins which precipitates isoelectrically between pH 5.0 and 6.5, since it is clear that part or all of this will in any case be precipitated after rigor mortis in normal muscles, i.e. those attaining an ultimate pH of 5.5. It is most probable that under severe conditions of pH and temperature, other sarcoplasmic fractions will be denatured in situ. Thus, there is normally more sarcoplasmic protein in an undenatured form in post mortem muscle of high ultimate pH and it is, therefore, obvious why subjection of muscle having a low ultimate pH to a subsequent high environmental pH is of less significance with respect to water-binding than an intrinsically high ultimate pH in the muscle itself.

Another possible lead to the nature of the biochemical changes occurring in AFD treated meat arose from the observation that, on homogenizing, reconstituted muscle fibres resisted breakdown to the level of myofibrils. A similar phenomenon has been noted when meat is subjected to large doses of ionizing radiation, or on prolonged storage. It seemed reasonable that there might be some intrafibrillar structural component which was susceptible to the AFD process and thus determine the degree of cohesion of the myofibrils. Veratti described a very delicate network in skeletal muscle which appeared to surround the myofibrils, and he devised a technique for its demonstration; this network has recently attracted the attention of electron microscopists who have described it as a fine tubular structure. It is now referred to as the "sarcoplasmic reticulum".

Veratti reported, and the present results confirm, that impregnation of an entire section of tissue is rarely complete. The variability of the reaction from fibre to fibre has been demonstrated for semimembranosus muscle from the control steer (non-dehydrated).

There was a complete failure to stain in sections of muscle which had been subjected to the AFD process. This difference between freeze-dried and non-dehydrated material was not affected by the ultimate pH of the muscles, but the significance of this finding in relation to "woodiness" has yet to be ascertained.

Notwithstanding these indications that the water-binding of AFD meat may be altered because of changes in the sarcoplasmic proteins or in the sarcoplasmic reticulum, careful studies of the extractability of myofibrils after their isolation from fresh, frozen and freeze-dried meat, at varying ionic strength and pH, have not revealed any significant difference in behaviour.

It is hoped to elucidate these matters further by electron microscopy and nuclear magnetic resonance.

PECTINASE INHIBITOR IN GRAPE LEAVES

by
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Pectic and cellulosic substances are the most abundant organic materials in fruits and vegetables and their chemical changes have been related to texture and quality in food processing. The softening of brined cucumbers under commercial conditions was demonstrated to be caused by pectinolytic and cellulolytic enzymes by Drs. Etchells and Bell, working at the Southern Division's U. S. Food Fermentation Laboratory in Raleigh, North Carolina. In addition they discovered the inhibitory activity of water extracts of grape leaves against these enzymes. Work at this Laboratory on the identity of the grape leaf inhibitor stems from their work. I am sorry that Dr. Etchells could not accept our invitation to tell you of their studies. However, I will try to cover it in the limited time available to me.

It has been known for years that cucumbers frequently soften during the brine fermentation prior to the final pickling operations and that once it occurs, little or nothing can be done to overcome this detrimental result. Drs. Etchells and Bell traced the softening action to the enzymes pectinase (polygalacturonase) and cellulase and proved that they were produced by fungi in the dead flowerets which stick to some of the cucumbers and are carried into the vats. Washing and sterilizing the cucumbers prior to packing in the vats or draining and refilling with new brine were shown to be impractical both from an economic and chemical basis, although this practice is carried out at the present time through necessity. Le Fevre, in 1927, recommended the use of grape leaves in making fermented dill pickles for home use since they made a suitable covering and had a greening effect on the pickles. Drs. Etchells and Bell, in checking some of Le Fevre's work, noted that the cucumbers did not soften in the presence of grape leaves. Although the use of grape leaves in cucumber pickles had been handed down from one generation to another in home pickling procedures and in very old recipe books, it was not until this work that the true value of grape leaves was demonstrated in the scientific literature. They found that water extracts of Muscadine grape leaves would inhibit the activity of pectinase both in the brines and in the test tube.

In addition, they developed a viscometric method for measuring the pectinase activity of salt brines and another for measuring the inhibitory activity of various water extracts of plant tissues. They showed that the inhibitory factor in grape leaf extracts is stable to boiling temperatures, that it does not dialyze through a cellophane membrane, that the inhibitory activity is of a competitive type, and that the material is also active against cellulase, although at a lower level than against pectinase. They demonstrated, in addition, that the level of inhibitory substance is different in the leaves of various varieties of grapes. In cooperation with us, they also demonstrated certain other sources of inhibitor containing plant tissues. This is a very short time to spend on an excellent piece of work but it serves to lead up to the work done at the Eastern Laboratory on the identity of the specific factors involved in the inhibition.

The Eastern Laboratory was given the task of isolating and identifying the active principle in Muscadine grape leaves. Certain data from Dr. Etchells' laboratory. namely the removal of the active principle from grape leaf extracts by means of strong base anion exchange resins, indicated the possibility that the active factor was an organic acid. However, preliminary experiments using anion exchangers in the borate form showed irreversible adsorption. This indicated that ordinary organic acids were not involved. In addition, weak base anion exchangers in the hydroxyl form would not remove the active principle even after salt-splitting with a cation exchanger, indicating the material to be slightly acidic and probably a hydroxy compound. Further tests led us to the hypothesis that it was a polyphenol of some nature. Since we knew it was not dialyzable, this eliminated many of the simpler types of polyphenols. It was found that nicotine and caffeine, added to the water used for extraction, prevented removal of the active principle. Addition of these reagents to a water extract gave negative activity after filtration. All extracts gave positive ferric chloride tests. Treatment of extracts with hide powder removed the active principle. These tests suggested tannin or tannin-like materials. Hide powder analyses of extracts from numerous plant sources showed that no direct relationship existed between tannin content, by this method, and inhibitory activity. However, certain groups of plants, including Muscadine grapes, Serecea and others, seemed to have a high activity in relation to the amount of tannin present. This indicated that different types of tannins had different levels of inhibitory power, especially in view of the fact that some plant materials with high tannin content had extremely low levels of inhibition. On this basis, a paper was published on the "Probable Identity of the Pectinase Inhibitor in Grape Leaves" stating that the active material was a tannin or a tannin-like material.

By modifying a patented process, we found that the inhibitory tannin could be precipitated completely by caffeine at low temperature. The precipitate, after resuspending in water, could be extracted with chloroform to remove the caffeine and resolubilize

the tannin. Freeze-drying of this material yielded a light tan, fluffy residue having 100% of the activity of the original solution but representing only about 40% of the tannin content as measured by the hide powder method. This material was shown by light scattering measurements to have a weight average molecular weight of about 250,000 (as compared to 600-3000 for tannins employed in commercial leather tanning). Sedimentation studies showed a broad range of molecular weights. Therefore, the range is from about 10,000 (as determined by dialysis) to somewhere in the millions. Whether these high values are due to a range of descrete molecules or due to aggregation cannot be determined at this time. Paper chromatographic analyses do not help in this matter, probably because of the extremely high molecular weight.

Paper chromatography of the original extracts showed one spot remaining at the origin, two others which moved somewhat but were in very low concentration, and a broad fluorescent streak was apparent in all chromatograms. The isolated tannins produced only one spot, remaining at the origin, and produced a slight trace of streaking detected only by fluorescence under ultraviolet light.

This isolated material produced red, insoluble phlobaphenes, almost equal in weight to the original sample weight, when sulfuric acid hydrolysis was attempted. Ether extracts of the filtrate gave one strong spot and one weak spot on paper chromatograms. The strong spot had the same R_F value as gallic acid and produced the same color reactions on paper with $FeCl_3$ and ammoniacal $AgNO_3$ and in solution with KCN. Reaction with ammoniacal $AgNO_3$ and p-anisidine and the R_F value, on papergrams of the filtrate, indicated the sugar moeity to be glucose. The presence of gallic acid and glucose in the hydrolysates may be due to the presence of a slight trace of hydrolyzable tannins not easily separated from the main tannin fraction. These results point definitely to the tannin being of the condensed type rather than of the hydrolyzable type. Being a condensed tannin, further work on structure has been stopped since there is so little chance of obtaining positive results in a reasonable time. Since synthesis is out of the question, further structure studies could not help much in searching for new and more economical sources of the natural inhibitor. In addition, the viscometric method for determining inhibitory power is quite reliable for use in scanning new source materials.

To summarize, a compound has been isolated from grape leaves which inhibits the activity of pectinase and, to a lesser extent, cellulase. The inhibition is of the competitive type. It has been demonstrated to be a condensed tannin of extremely high weight average molecular weight with a wide range of molecular size. Whether these high values are due to a range of discrete molecules or due to aggregation is not now known. All plants

do not contain tannins of equal inhibitory power. Grape leaves are not an economical source of the material but preliminary studies have indicated new sources which may be developed. The isolation procedure gives a method which appears promising for the economical extraction and preparation of an inhibitor-rich material, essentially free of other plant constituents. Further work on laboratory and commercial use of the material for preventing cucumber softening during brine fermentation is necessary and will be carried out by Drs. Bell and Etchells. In addition, the use of this natural inhibitor in other food preparation applications, where pectinase or cellulase play a detrimental part, is entirely possible and should be investigated.

More detailed research data are reported in the following publications:

1. Probable Indentity of the Pectinase Inhibitor in Grape Leaves.
W. L. Porter, J. H. Schwartz, T. A. Bell, and J. L. Etchells.
J. Food Science, 26: 600 (1961).

2. Inhibition of Pectinase and Cellulose by Certain Plants.
T. A. Bell, J. L. Etchells, C. F. Williams, and W. L. Porter.
The Botanical Gazette, 123: 220 (1962).

3. Isolation and Description of the Pectinase-Inhibiting Tannins of Grape Leaves.
W. L. Porter and J. H. Schwartz.
J. Food Science, 27: 416-418 (1962).

PSYCHOLOGICAL MEASUREMENT OF FOOD PROPERTIES[1]

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[1]This paper reports research undertaken at the Armed Forces Food and Container Institute, U. S. Army Quartermaster Research and Engineering Center, and has been assigned number 2246 in the series of papers approved for publication. The views or conclusions contained in this report are those of the author(s). They are not to be construed as necessarily reflecting the views or indorsement of the Department of Defense.

(For Summary of this paper see page 40 of this report.)

FRUIT FLAVOR RESEARCH

in the Western Utilization Research and Development Division

by
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Fruit flavor studies at the Albany and Pasadena Laboratories have been conducted in two broad areas, namely, studies of the citrus essential oils and the fruit juice aromas. Because of the basic difference in composition between these materials, compositional studies have followed different paths. In both systems the extreme complexity of the mixtures has necessitated the use of the newest separation techniques such as column chromatography, thin layer chromatography and gas liquid chromatography. No single technique in itself, however, has been completely satisfactory and combinations of these have been used. In the analysis of the citrus oils, chemical reagents were also used which permitted the separation or elimination of classes of compounds. The resulting mixtures were simpler and could be handled by gas liquid chromatography (GLC). In such separation schemes, the possibility of introducing artifacts must be kept in mind and tested for.

For the citrus oils a first separation into hydrocarbon fraction and more polar components was made by column chromatography on powdered silicic acid. For routine analyses thin layer chromatography was used to separate the hydrocarbons by downward development. Enough solvent was collected to elute off the hydrocarbons and the resulting eluate analyzed directly by GLC. Butyl benzene was used as an internal standard for determining total mono-terpene (C_{10}) content and naphthalene for total sesqui-terpene (C_{15}) content. This provides a rapid means for determining degree of folding in deterpenated oils. It was used for elucidating the relationship of hydrocarbon composition of lemon oils to optical rotation and for demonstrating that oxidation of one hydrocarbon, gamma-terpinene, in lemon oils was responsible for the formation of p-cymene and the associated "cymie" off-flavor. In a study of hop oils the hydrocarbon fraction was further broken down by removal of conjugated dienes with maleic anhydride in the Diels-Alder reaction.

The more polar components may be eluted with polar organic solvents from silicic acid columns after removal of the hydrocarbons and analyzed directly or may be further separated with chemical class reagents. The Girard reagent was used to remove aldehydes and ketones from this polar fraction as water-soluble betaine hydrazones. The ketones are poorly regenerated with excess formalin, but aldehydes, under suitable conditions are well regenerated and the resulting aldehyde mixture was analyzed by GLC. More time or elevated temperature is required for regenerating alpha-, beta-unsaturated aldehydes than for

regenerating the saturated aldehydes. This and the effect of varying the pH of the developing mixture have been used to further separate the aldehydes. The remaining mixture of polar components left after removal of the aldehydes was analyzed by GLC and then saponified and the free acids formed removed to analyze for alcohols and unsaponifiable material. In the study of hop oils the hydrocarbons were removed by column chromatography on alumina, the carbonyls removed with Girard's reagent and the remaining mixture of esters and alcohols treated with adipyl chloride to remove primary and secondary alcohols. The residual ester and tertiary alcohol mixture was analyzed by GLC and then saponified and the free acids methylated and the methyl esters analyzed by GLC. The methyl esters were further separated by clathrate formation with urea which complexes with acids having a seven carbon unbranched segment adjacent to the carboxyl.

The above class reagent procedures are useful in general compositional surveys and in studying changes in composition in fruit varieties or changes resulting from processing and storage of products.

For studies of volatile components in juices and fruits, direct analysis of the vapors with GLC on packed and capillary columns using a flame ionization detector which can tolerate the presence of water was used. This is a modification of the dual-column system of McWilliams and Dewar. The carrier gas was deliberately saturated with water vapor. For isolation of components for chemical study, essence recovery and extraction followed by distillation, preparative GLC and column chromatography were used. Fractions were analyzed by capillary GLC in which the column was coupled directly to a time-of-flight mass spectrometer. This system can provide considerable information on the composition of the individual components and requires very small amounts of material.

Taste panel evaluation is employed to determine the contribution of the various fractions from the volatiles of orange juice to flavor. A bland powdered juice to which a threshold level of peel oil has been added is used as a base. Studies are continuing also on methods for incorporating recovered essences, extracts and oils into powders. Currently the best method appears to be "locking in" in an amorphous mixture of sugars. Improvements have been made in the locking-in equipment. Other solid carriers are under study.

ABSTRACT

CHEMICAL CHANGES ACCOMPANYING FLAVOR DETERIORATION OF VEGETABLE OILS[1]

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Conditions that prevent oxidation, promote the flavor stability of vegetable fats and oils. Heat, light, and oxygen are the main contributing agents to the deterioration of fats, and of these oxygen is the most incidious. Hydroperoxides are generally accepted as the initial product of oxidation, and although they are unstable, the various isomeric hydroperoxides of the unsaturated fatty acids can be isolated and studies.

Hydroperoxide decomposition in the presence and absence of oxygen, and under various storage conditions, was discussed. Methyl linoleate hydroperoxides decompose at a surprisingly rapid rate even when stored at 0° C. and under nitrogen. When stored under oxygen, the rate is increased fourfold, and the products of decomposition are sission acids, dimers, and other polar products. When isolated hydroperoxides are thermally decomposed in the absence of oxygen, about 10% by weight of the material goes to volatile products, and about 90% remains as polymeric and dimeric materials.

The volatile hydroperoxide decomposition products are composed of a series of hydrocarbons, aldehydes, ketones, alcohols, and esters. These products are found both as saturated and unsaturated materials.

Decomposition of the hydroperoxides is by a free radical mechanism with rupture of the fatty acid carbon chain occuring on either side of the carbon atom containing the hydroperoxidic group (reactions C and D). Either before or simultaneous with the chain breaking, a homolytic splitting of the hydroperoxide radical occurs (reaction B) producing a free hydroxyl radical and the fatty acid hydroperoxide free radical. The isolation and the identification of a series of saturated and unsaturated hydrocarbons and semialdehydes are evidence for the fatty acid chain rupture as shown by reaction C. The splitting, as shown by reaction D, gives rise to many saturated and unsaturated aldehydes.

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[1]Presented at Eastern Experiment Station Collaborators Conference on Flavor and Texture of Foods, Eastern Utilization Research and Development Division, Philadelphia, Pennsylvania October 30-31, 1962.

[2]A laboratory of the Northern Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture.

A. $R\text{-}CH_2\text{-}CH{=}CH\text{-}(CH_2)_7\ COOR' + O_2 \longrightarrow$

$R\text{-}CH{=}CH\text{-}\underset{\underset{OOH}{|}}{C}\text{-}(CH_2)_7\ COOR'$

B. $R\text{-}CH{=}C\text{-}\underset{\underset{OOH}{|}}{C}\text{-} \longrightarrow R\text{-}CH{=}C\text{-}C\text{-}$

$O\cdot + \cdot OH$

C. $R\text{-}CH{=}C\text{-}\underset{\underset{O\cdot}{|}}{C}\text{-}C$ $\longrightarrow$ Hydrocarbons, Alcohols, Semialdehydes

D. $R\text{-}CH{=}C\text{-}\underset{\underset{O\cdot}{|}}{C}\text{-}C$ $\longrightarrow$ Aldehydes, Esters, Hydroxy esters

Other types of splitting of the hydroperoxides are known to occur since split products of known structures, not compatible with the type of breakdown described above, have been isolated. Breakdown of the hydroperoxides in the presence of oxygen would be expected to be different because of the strong tendency of oxygen to capture free radicals.

Dimeric and polymeric materials arise from several sources in autoxidized fats. The structure of these materials is unknown, and present evidence indicates that there may be many structures present covering a wide range of molecular weights. A dimeric product, i.e., a product having twice the molecular weight of the natural C-18 fatty acids, can be readily separated by vacuum distillation to the extent of 60-70% of the weight of the residues. Higher polymeric materials are also known to be present as are extremely polar materials of a complex structure. The highly polar products are of lower molecular weight and may be thermal condensation polymers of unsaturated aldehyde-esters and heto-esters. Natural vegetable fats are known to contain polymeric materials to the extent of 1.5 to 2.0%, and the amount of this material is known to increase directly with the autoxidation of an oil. At low peroxide levels a correlation coefficient of 0.97 is obtained between peroxide values and polymer content after deodorization of the oil. Such an analysis can be used as a measure of the total amount of oxidation or the amount of "hidden oxidation" to which a given oil has been exposed.

Fractionation and separation of dimeric material have been accomplished by countercurrent distribution and liquid-liquid chromatography on silicic acid. Pure thermal dimers made by heat polymerization of conjugated methyl linoleate can be chromatographed and separated from nonpolymerized esters by chromatography.

Oxidative polymers made by heat decomposition of methyl linoleate hydroperoxides give rise to a complex polymer, which can be freed from the monomer by distillation. Chromatography of the oxidative dimers, first as an ester and then as an acid, shows that the polymer is split into two major fractions; one major fraction behaves chromatographically like the thermal dimer and the more polar fraction as the oxidative portion. By making three chromatographic determinations on the dimer fraction, first as the ester, then as the free acid, and then upon the reesterified acids, it is possible to determine thermal and oxidative dimers in the presence of each other. The method has been developed on dimers prepared from methyl linoleate; only limited application has been made to studies of autoxidized fats.

FACTORS THAT CAUSE CHEMICAL AND FLAVOR DIFFERENCES IN POULTRY

by
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Before it is consumed, poultry is exposed to many factors. These factors are varied, often drastically, to increase efficiency. However, efficiency should not be achieved by unduly sacrificing quality. Therefore it is important to know how these factors affect the flavor and chemical properties of poultry.

Observations on the effect of age and sex (2), and variety and breed (2,3) on poultry flavor have been reported. These results generally indicate that these factors have so little effect on flavor that considerations other than flavor should determine the age, sex, variety and breed of poultry used.

It is well known that feed composition can influence the fat/protein ratio. It is also known that feed composition can affect the fatty acid composition (5), the tocopherol content (10), and the stability (7) of poultry carcass fat. Also it has been established that the inclusion of fish oil and linseed oil in poultry feed can cause fishy off-flavor in poultry (6,7). On the other hand the effect of feed composition on typical, desirable poultry flavor is relatively obscure. For example, it remains to be convincingly demonstrated that poultry flavor can be increased or improved to any important degree through the use of special feed ingredients.

It is known or suspected that many other factors cause chemical and flavor differences in poultry. Post-mortem chemical changes, type of tissue, temperature, oxygen availability during storage

and cooking, canning, dehydration, and irradiation are some examples. More scientific information is needed to help determine how these factors can be controlled so that optimum fresh flavor can be developed and maintained. To obtain some of this information, chemists have studied the chemical nature of poultry flavor and have sought to relate chemical differences with factors which cause flavor differences.

Hydrogen sulfide and ammonia (11) and approximately twenty carbonyls (12) have been identified among the volatiles of cooked chicken. The principal carbonyls identified were acetaldehyde, hexanal, 2,4-decadienal, diacetyl, and acetoin. Evaluation of the odor of a mixture of volatile components identified has not been attempted. It is known that the characteristic odor of cooked chicken cannot be attributed to any single volatile component identified. What is known about the role of these volatile components in poultry flavor and the nature of their precursors has been recently described, (8).

Gas chromatography has been used to determine the effect of some factors on the volatile fraction of chicken (9,13). Cooked, compared to uncooked chicken, yielded a relatively large and complex volatile fraction. Volatiles from a mixture of chicken skin and skin fat were qualitatively similar to but quantitatively much larger than volatiles from lean chicken meat. Volatiles of chicken cooked in air were quantitatively much greater and apparently more complex than volatiles of chicken cooked in nitrogen. Rancid chicken yielded volatile components apparently similar to those observed in fresh chicken but the yield of volatiles was greater from rancid than from fresh chicken. Rancid, compared to fresh chicken, showed particularly greater amounts of 2,4-decadienal and hexanal.

There is some evidence that pH influences chicken flavor. One worker found that chicken flavor was most strongly developed at pH 1 to 4, to a lesser extent at pH 4 to 7, and that atypical flavors resulted at pH 7 to 8 (1). Another worker has demonstrated that ammonia, hydrogen sulfide, and diacetyl increase as the pH is increased from 5 to 7 (4). Others have observed a correlation between flavor and chicken broth pH (2), but have not explained why this correlation exists.

Thus, results generally indicate that the quality of poultry flavor today compares favorably with that of yesterday and has not suffered as a result of variations in production factors. However, further information is needed about the flavor characteristics of various chemical components before the chemical results can contribute in a major way to the development and maintenance of optimum flavor in the wide variety of poultry products that are of commercial interest.

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CHEMISTRY OF DAIRY FLAVORS

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All three of milk's principal components contribute to the flavor of dairy products. Lipids. The finely dispersed globules of milk fat supply much of the pleasing flavor to milk, cream, butter and ice cream. Milk lipids are unique in that they contain about ten mole per cent of combined butyric acid, together with a liberal proportion of C_6, C_8 and C_{10} fatty acids. All these exist free in trace amounts. At normal concentrations they undoubtedly contribute to the characteristic flavor of milk and milk fat. Naturally occurring carbonyls are potentially significant to milk flavor. Aldehydes arising from plasmalogens and triglycerides may serve as the origin of off-flavors in dairy products. It is not known whether such compounds are significant to the natural flavor of milk fat. In unheated milk fat acetone is the predominant methyl ketone. The entire series of odd number methyl ketones through C_{15} have been found in heated milk fat, dry whole milk and evaporated milk. β-keto acids and keto-glycerides (intermediates in fat synthesis) apparently are the precursors. Delta-lactones are a key class of compounds distinguishing the flavor of milk fat. The quantity in milk fat is increased by heat and delta-hydroxy acids and glycerides (from fat synthesis) are the precursors.

Proteins. Physical stability of the proteins in milk has a marked effect on the tactual element in flavor. The serum proteins have been associated with the astringency defect in reconstituted dried milks. Much market milk has cooked flavor, attributed in part to H_2S released from β-lactoglobulin. It is likely that other compounds derived from proteins also contribute to this off-flavor. Basic amino acids, especially lysine, have been implicated in heat-induced browning reactions. During normal storage of dairy products browning reactions can proceed slowly and lead to flavor deterioration.

Lactose. About 5% of milk is lactose, which provides the pleasant sweet taste. Milks differ in their salty-sweet character and since lactose varies inversely with chloride content, milks high in chloride taste somewhat more flat or salty than normal. Lactose is a major energy source for microbes in cultured dairy products, hence is a precursor to certain flavors. Lactose is important in browning reactions.

Volatile Components of Milk Flavor. Chemical definition is incomplete. Short chain amines, acids, acetone, ammonia, acetaldehyde, acetonitrile and methyl sulfide have been identified. Methyl sulfide is believed to be the most significant. Slightly above its threshold concentration, 12 parts per billion, methyl sulfide exhibits a typical milk odor. The optimum concentration appears to be very critical, and if much exceeded the odor may be characterized as malty or cowy.

Butter. Although it is well recognized that diacetyl is a key component in cultured cream butter flavor, all evidence indicates that the total flavor is derived from a number of compounds, the ratios of which are critical in providing the proper balance of flavor. An attempt to establish the optimum levels of short chain acids and diacetyl in butter has given the following (tentative) results: diacetyl, 2.45 ppm; lactic acid, 509 ppm; formic acid, 31 ppm; acetic acid, 37 ppm. Other compounds identified include esters, alcohols, aldehydes, ketones, acetoin and methyl sulfide.

Cheddar Cheese Flavor. Proteolysis and lipolysis are the gross compositional changes evident in cheddar-making. The importance of milk fat in cheddar flavor is apparent on comparing cheese made from skim milk with one made from whole milk. No very significant correlation has been found between flavor and the quantity of short chain fatty acids but this point should be re-evaluated in light of new findings. There is evidence of δ-lactones in cheddar. Typical cheddar aroma has been attributed to the neutral fraction of the volatiles, so the flavor must arise from substances other than the initial products of fat and protein hydrolysis. The amino acids are subject to deamination and decarboxylation to yield a variety of compounds. Direct evidence for the Strecker degradation in cheese has not been reported, but the reactants--dicarbonyls and amino acids--are present. It is claimed that relatively simple mixtures made from some of the numerous compounds found in cheddar cheese provide a good approximation to cheddar flavor. Among the mixtures are acetic and butyric acids, methionine and butanone; methyl ketones and certain fatty acids; and amino acids, carbonyls and β-mercaptopropionic acid. There is a measure of disagreement with all these proposals. Doubtless more attention should be given to the possibility of interaction among compounds and to the inherent instability of some of the reaction products. The flavor of blue cheese has been more accurately defined than that of any other cheese. The major flavor components are fatty acids, odd numbered methyl ketones, and secondary alcohols.

Additive Interaction of Carbonyl Compounds at Subthreshold Levels. When defining a flavor chemically we are always confronted with the problem of determining the relative importance of various compounds. In some foods only a few compounds comprise the flavor, whereas in others the flavors are very subtle and complex. Particularly in the latter case, the possibility of interaction among flavor compounds at subthreshold concentrations to produce a detectable flavor--or off-flavor--has many implications. In off-flavor development it is conceivable that when any objectionable compound reaches its flavor threshold the flavor defect would become evident. These points have been the basis for current research on the relative contribution of various carbonyl compounds to oxidized flavors in milk fat. Well over 25 volatile carbonyl compounds have been identified in oxidized milk fat. Although some have concluded that the flavor defect is caused by a single component, our own observations indicate that the flavor is not only due to more than one compound but that additive interaction of compounds is significant also.

CHEMICAL FACTORS IN MEAT FLAVOR

by
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The precursors of the volatile contributors to lean meat flavor are water extractable. Lyophilization of these extracts yields water-soluble powders. Heating these powders in a specially designed all-glass apparatus at 100°C under high vacuum yields a volatile fraction that can be trapped out at liquid nitrogen temperature. Subsequent fractionation under vacuum yields two major fractions. The least volatile of these two fractions, on exposure to air, assumes a highly desirable, meaty aroma. Over 90% of this fraction is lactic acid and its ammonium salt. The aromatic substances in this fraction have been separated chromatographically and examined spectrophotometrically, but their identification is not complete. The more volatile of these two fractions has a characterestic, not too pleasant, odor. These volatiles have been analyzed for carbonyl compounds, acidic and basic compounds and for sulfur-containing compounds. Lean beef, pork, and lamb powders yield surprisingly similar results. The compounds isolated are qualitatively similar, as are the spectrophotometric and chromatographic data obtained from fractions not completely identified. The powders obtained by lyophilization of these water extracts have been refluxed in water and heated in air, and the aromas have been evaluated for flavor contribution. Species differences are not detectable in the volatiles, but the same basic meaty aromas are obtained from the three types of powders. To see if this generalization might be widely applicable, whale meat was also carried

through our vacuum pyrolysis procedure. The results were quite similar to those obtained using beef, pork, and lamb, with the exception that large amounts of trimethylamine were also found. Trimethylamineoxide may well be distributed throughout the lean meat of the baleen-type whale since it is present in the crustaceans the whale feeds upon. Bacterial action will quickly reduce this compound to trimethylamine. However, even in this marine mammal, the same basic meaty flavor is produced from the lean meat. Lean meat flavor precursors were separated on the basis of size by dialysis and Sephadex gel filtration. The protein fraction did not contain flavor precursors. The low molecular weight fraction was lyophilized and the white, fluffy powder vacuum pyrolyzed as described. The familiar pattern of odors and compounds were obtained, indicating that the flavor precursors were in this fraction. Separation of this fraction into amino acids and carbohydrates gave sub-fractions that did not yield meat-like aromas on heating. Recombination of the sub-fractions and subsequent heating gave the desired aromas. Thus, lean meat flavor can be attributed to a "Browning" type reaction between amino acids and carbohydrates.

Species differences were found to reside in the fat of beef, pork, and lamb. Characteristic beef and pork aromas could be obtained from fat heated in air but not under vacuum or in nitrogen. Characteristic lamb flavor could, however, be obtained from lamb heated in nitrogen or in air. Major qualitative and quantitative differences exist in the free fatty acids and carbonyl compounds present in these fats, both before and after heating in air or nitrogen or vacuum. Further studies on lamb fat have shown that the characteristic lamb flavor is not a product of fatty acid oxidation but is carbonyl in nature and presumably present as a lipid soluble material in the fat. Phospholipids in lean meat were extracted and separated into lecithins, cephalins, and sphingomyelins, and their fatty acid composition determined. An evaluation of phospholipid contribution to flavor indicated that these compounds contribute to off-flavor rather than to desirable flavor. It is concluded that lean meats contribute a similar basic meaty flavor and that species flavor differences reside in the fat. Profound effects on flavor may be exerted by extraneous materials stored in the fat, as is apparently the case in lamb. This may be also true for the lean meat, which is essentially an aqueous phase, as in the case of trimethyleneoxide in whale meat.

PSYCHOLOGICAL MEASUREMENT OF FOOD PROPERTIES

by
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Food has many properties whose measurement helps the physical scientist and technologist understand and manipulate it to gain desired ends. But food is for people, and their reactions to it are important. The appropriate techniques for investigating such behavior are called psychological measurement. Flavor, taste, odor, texture, consistency--these things are often considered as properties of foods--but perhaps it is more valid to look on them as properties of peoples' behavior toward foods in recognition of the fact that they are subjective realities. Certainly, they arise from physical stimuli, but the stimuli are not the properties. Further, more often than not, interest is focused not on description of foods, but on its evaluation in terms of preference, hedonic tone, and user acceptance. Here, clearly, one is dealing with "people properties" rather than food properties.

Foods people have played the major role in the growing discipline of sensory evaluation. They first recognized the problems and sought practical solutions, although, too often working on a catch-as-catch-can basis. They far outstripped the mother science of the discipline, psychology, which long ago had laid down the basic precepts, theories, and general operating principles. But psychologists were loathe to soil their reputations by dealing with the kinds of practical problems that faced the food technologist, hence their contribution was minimal until recent years.

Psychology is a primary source for guidance since it deals constantly with human functioning--sensations, perception, ideas, judgment, learning, memory, attitudes, etc. Psychology has a vast fund of general knowledge about these things. To work in the field one need not be a trained psychologist, but he should acquaint himself with the relevant background.

The data dealt with in sensory evaluation tend to be more variable than data from physical measurement. Traditionally, the behavioral sciences have been interested in mathematical methods of understanding and accounting for variability. Thus, the statistical approach is important if effective work is going to be accomplished; however, psychological measurement and statistics are not synonymous. Statistics, plus common sense, is not enough. Also needed is the core of information and know-how that relates to the human behavior which is being investigated.

Scientific sensory evaluation of foods has always had major competition from the expert and expertism. Nearly everyone who works

with foods and flavors indulges in expertism to some extent. Its proper function lies in "bench-top" examination for the purpose of preliminary evaluation and the generation of hypothesis about the progress of the work. There are certain obvious dangerous in expertism, for example, an expert is a very small sample of the population and is also very likely to be biased. "Expert type" results should be used only with caution.

Methodology is the key factor in psychological measurement, and it is in this critical area where confusion has been the order of the day. Many different methods have been, and are being, used, ranging from the completely inadequate to the fully valid. Some effort at taxonomy will help to clarify our thinking.

Tests can be classified according to the kind of psychological functioning required of the subject:

(a) Affective. Here we are dealing with preference, pleasure-displeasure, like-dislike. Emotion and feeling are more important than reasoning. This is the common type of test in evaluation. It can even be shown that the opinions of trained experts about quality fall in this category.

(b) Discriminative. This is a broad category including most tests not included above, where we are dealing in opinion, judgment, deliberation. They may be concerned with difference per se, or difference on a specified dimension. Once the dimension is specified and clearly understood, such tests are fairly reliable.

(c) Descriptive. Perceptions of flavor, or of anything else, are made up of many separable impressions. These qualitative dimensions hold the key to peoples' differential behavior toward products. Since they are related to physical properties of things, knowledge of them is an important aid in manipulating flavor to desired ends. This is the task in descriptive analysis --sorting out these various dimensions, identifying them, and estimating their importance.

A more common way to classify is according to test form--a classification not entirely independent of test purpose:

(a) Paired comparisons - two samples presented together to be compared on the basis of some designated criterion.

(b) Rank order - a set of samples (more than 2) presented together to be aligned in order according to some criterion.

(c) Rating scale - the dimension of judgment is represented as a linear continuum divided into successive degrees. Samples are usually presented singly (though not necessarily so) and each is assigned to a point on the continuum.

(d) Discrimination - best represented by the familiar example of the triangle test, where two identical samples and a different one are presented and the subject tries to pick the odd sample. Many different forms are possible; the essential thing is to create a situation where the subject is forced to select one of a strictly defined set of behaviors and where we can label his response as "right" or "wrong" according to the known properties of the samples.

(e) Attribute identification - consists simply of noting whether or not a specified quality is present.

(f) Descriptive analysis - this is defined, circularly, as the kind of test that produces descriptive data. It is a "catch-all," because there may be a variety of forms.

Another way to look at psychological measurement, although not strictly a mode of classification, is according to the kind of standard employed. Physical measurement depends upon objectively real standards simultaneously present; in contrast the standards in psychological measurement frequently rely on the function of memory. Some examples:

(a) Standard physically present in the test situation and so designated, as in the triangle test.

(b) Standard physically present for reference but not part of the formal test, e.g., assigning a given value to a "control" sample in a rating scale test.

(c) Standard represented by general attitudes, or response tendencies, arising out of experience, as in the hedonic scale preference test.

(d) Standard represented in a specific concept, as in determining whether a product is adulterated with a certain compound.

An important feature in the design of a sensory test is the dimension of evaluation. This may affect both the amount of variability and the validity. The aspect of the sample that is to be considered should be clearly defined, and failure to do so is a serious failing. Some dimensions are easily understood (e.g., difference per se, preference, and common taste qualities, such as sweet, salt, sour, and bitter). Others may be interpreted in different ways by different people (e.g., rancid) or may have meaning only to panel members who have had special training. Confusion of dimensions is the major difficulty which besets descriptive analysis tests.

The sampling of people to participate in tests represents another unsolved problem. Procedures are available for drawing proper samples to represent given populations but seldom are they applied in the laboratory context. Here the usual criteria of selection

are: physically and administratively available, reasonably well-motivated, and not definitely subnormal in sensitivity and skill. Intuitively, we feel that such panels are fairly representative of the general population and this can sometimes be empirically verified; however, there is no real assurance of this fact.

Experience has shown that spending a great deal of effort on the selection and training of test subjects is not warranted. It is not possible to select and train for all of the characteristics which are important in good performance, e.g., interest, motivation and continued stability of judgment. A method found to be generally satisfactory is to start with a large panel, eliminate those who demonstrate relative inability to discriminate, and continuously review panel performance.

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